Using Ground Penetrating Radar to Characterize Anthropogenic Landscapes of New York City

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Introduction

The United States Department of Agriculture - Natural Resources Conservation Service is using ground-penetrating radar (GPR) to characterize anthropogenic landscapes. GPR is an impulse radar system designed for relatively shallow investigations. Pulses of electro-magnetic energy are radiated into the ground from a transmitting antenna. Whenever a pulse contacts an interface separating layers of differing dielectric properties, a portion of the energy is reflected back to the receiving antenna. By moving an antenna along the soil surface, GPR can provide a continuous profile of the subsurface.

Compared with other geophysical techniques, GPR provides the highest resolution of subsurface features. Ground-penetrating radar does not work well in all soil environments. Soils having high electrical conductivity rapidly dissipate the radar's energy, restrict observation depths, and create low signal to noise ratios that impair image quality and interpretability. In highly conductive soils, the use of GPR is inappropriate. Use of GPR has been most successful in areas of sandy or coarse loamy soils. Generally, observation depths range from 5 to 30 m in sandy soils, 1 to 5 m in loamy soils, and less than 0.6 m in clayey soils.

Uses of GPR

- Estimate depths to soil horizons (Collins and Doolittle, 1987; Doolittle, 1987), dense till and bedrock (Collins et al., 1989).
- Distinguish features within landfills (Bowders and Koerner, 1982), detect potential contaminant plumes, facilitate monitoring-well placement (Koemer et al., 1981), and locate the boundaries of landfill sites (Lawton et al., 1994).
- Detect buried pipes and cables (Annan et al., 1984).
- Delineate and map water tables (Beres and Haeni, 1991).
- Estimate pavement thickness and detect voids beneath roads (Saarenketo and Scullion, 2000).
- Update soil survey reports (Johnson et al., 1980; Schellentrager et al., 1988).

GPR Systems

The radar units used were the Subsurface Interface Radar (SIR) System-2 and System-3 manufactured by Geophysical Survey Systems, Inc. (North Salem, NH). Antennas operate at center frequencies of 120, 200, 400 and 500 mHz. Lower frequency antennas achieve greater depths; higher frequency antennas provide greater resolution.

Field Procedures

Several anthropogenic landscapes in New York City (NYC) were characterized using GPR. Before fieldwork, historical data, aerial photographs, and topographic maps were reviewed to provide background information of the sites. At each site traverse or grid lines were laid out. Observation points were established along each line. A Global Position Systems (GPS) receiver was used to geo-reference the coordinates of grid intersections or observation points. Pulling an antenna along the traverse or grid lines completed the radar surveys. Radar records were reviewed in the field. Soil borings were used to confirm interpretations and to depth scale the radar record.

Site 1 - Characterization of an Abandoned Landfill (Human Refuse)

Site Description

The Brookfield Landfill is located in the town of Richmond, on Staten Island, New York City. The entire facility occupied about 70 hectares. However, only 61 hectares received refuse, the other portions of the site served as a buffer zone between the landfill and residential areas located principally to the south and east. A GPR survey was completed to map the thickness of the fill cap within the landfill.

Discussion

Based on interpretations of the radar profiles taken at the 115 observation points, the average thickness of the fill cap was 0.44 m with a range of 0.0 to 1.54 m. One-half of the observations had fill caps between 0.25 and 0.59 m thick.

Several series have been proposed for anthropogenic soils formed on landfills. Series criteria are based on drainage, types of materials, and depth to garbage. In areas where the cap is less than 0.61 m, reclamation is considered improbable. The Greatkills (loamy-skeletal, mixed, nonacid, hyperthermic Typic Udorthents) and the Freshkills (coarse-loamy, mixed, nonacid, hyperthermic Typic Udorthents) series have fill caps ranging from 0.18 m to 0.61 m and from 0.61 to 0.99 m, respectively. Centralpark (loamy-skeletal, mixed, mesic Typic Dystrudepts) and Greenbelt (coarse-loamy, mixed, mesic Typic Dystrudepts) soil series have been proposed for areas with fill caps thicker than 1.0 m.

Taxonomically, the survey area was 63 percent Greatkills soils and 16 percent Freshkills soils. About 16 percent of the observation points had fill caps that were too thin (less than 0.18 m) to be classified. About 5 percent of the observation points represented areas of included soils with fill caps greater than 1.0 m.

A two-dimensional plot simulating the thickness of the fill cap (or the depth to the refuse layer) across the survey area is shown in Figure 1. The fill cap cover is noticeably thicker in two places: a constructed ball field (A) and an elevated pad for model airplanes (B). The ball field (A) was mapped as Greenbelt soils and the model airplanes field (B) was mapped as Centralpark soils. Other areas were mapped as Greatkills soils and similar soils.

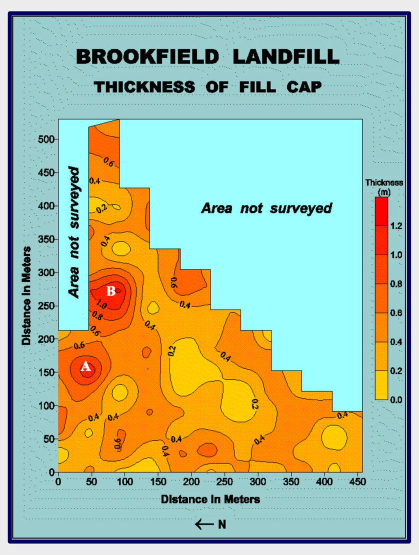

Figure 1. Two-dimensional plot of the study area showing the interpreted thickness of the fill cap.

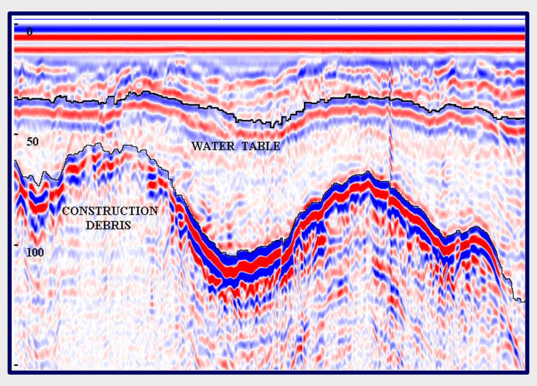

Figure 2. Representative radar profile from Gateway Estates.

Site 2 - Characterization of a Landfill (Watertable & Buried Construction Debris)

Site Description

The study area is located in Gateway Estates, Brooklyn. In the past, Gateway Estates was a component of the Jamaica Bay tidal marsh complex. The site was used for dumping of municipal waste such as construction debris, tires, and metals. In the 1950s, the site was capped with dredge materials from Jamaica Bay. Future uses of the site include the construction of a shopping center and low-cost housing. A GPR survey was completed to map depth to water table and construction debris.

Discussion

The GPR profile in Figure 2 was obtained with the 120 MHz antenna. The water table and buried layer of construction debris provide conspicuous subsurface interfaces.

Figure 3 shows the radar-interpreted depth to construction debris. In general, depths to construction debris tend to be greater in the central core area and are less near the periphery of the site. The average depth to construction debris was 1.83 m with a range of 0.43 to 3.82 m. One-half of the observations had depths to construction debris between 1.42 and 2.18 m. Variations in depth to construction debris are a result of changes in the thickness of the overlying sandy, anthrotransported dredge materials.

Figure 4 shows the interpreted depth to the water table. The water table was not apparent at 76 observation points. At a majority of these observation points, layers of construction debris occurred at depths shallower than the water table. Because of high rates of signal attenuation, the water table was not distinguishable within the finer-textured construction debris.

Within Gateway Estates, the average interpreted depth to the water table was 1.3 m with a range of 0.40 to 2.61 m. One-half of the observations had depths to water table between 0.97 to 1.59 m. Variations in the depth to the water table are attributed principally to variations in surface topography. Gateway Estate has an undulating surface with several dune-like features and depressions.

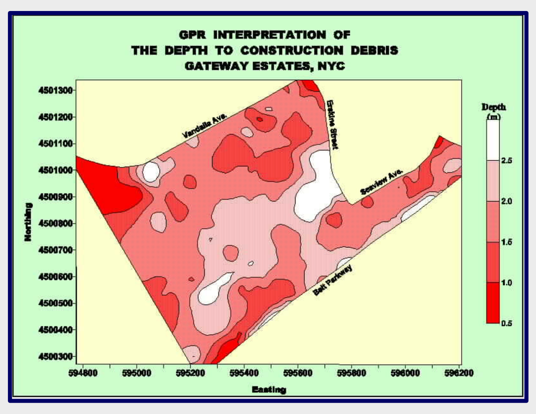

Figure 3. Two-dimensional plot of Gateway Estates showing the interpreted depth to construction debris.

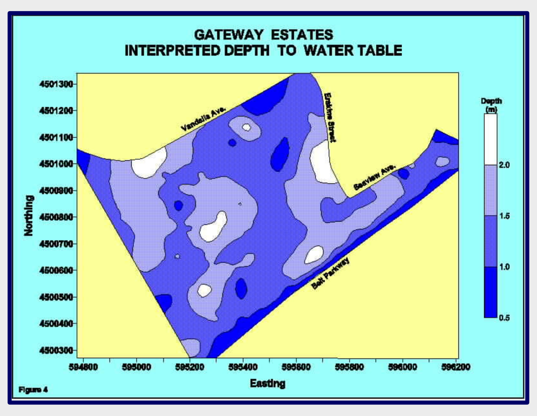

Figure 4. Two-dimensional plot of Gateway Estates showing the interpreted depth to water table.

Site 3 - Characterization of a Landfill (Fresh Watertable & Buried Peat Layers)

Site Description

Floyd Bennett Field was the first municipal airport of NYC. In 1928, the site chosen for the airport was Barren Island, a 157-hectare marsh with 33 small islands located in Jamaica Bay on the southern tip of Brooklyn. Six million cubic yards of sand were pumped from Jamaica Bay to connect the islands and raise the site to 5 meters above the high tide mark. The fill is mainly dredged sand, which overlies buried tidal marshes. The radar was used to profile the depth of buried peat layers and map the thickness of the fresh water saturated zone.

Discussion

Table 1 summarizes transect data collected with the GPR. The radar recorded the depths to water table and buried tidal marsh soils. However, the radar signal was severely attenuated by the buried tidal marsh materials. High rates of signal attenuation were attributed to the high clay, moisture, and salt contents of these materials. These materials restricted the GPR's observation depths. The plot maps show the interpreted depth to the water table (Figure 5) and the buried tidal marsh soils (Figure 6).

Table 1. Average Depth to Water Table and Buried Tidal Marsh Soils (all depths are in m)

Transect #	Length (m)	Observations	Average Depth Water Table	Average Depth Marsh Soils
1	1140	20	1.93	5.68
2	1059	17	1.93	5.74
3	931	17	1.89	5.97
4	771	28	1.80	6.39

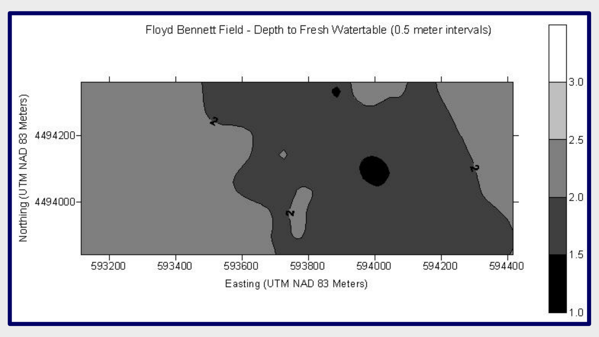

Figure 5. Two-dimensional plot of the study area showing the interpreted depth to water table.

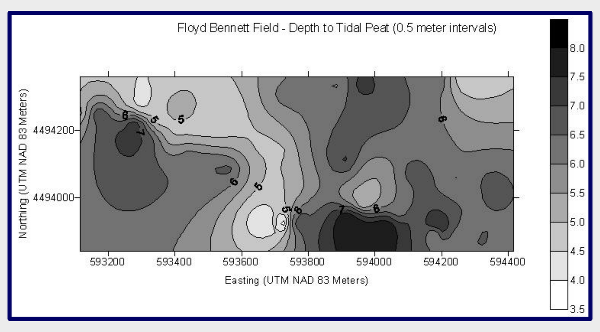

Figure 6. Two-dimensional plot of the study area showing the interpreted depth to buried peat layers.

Summary

- GPR techniques provided interpretative results for three anthropogenic landscapes.
- GPR was used to estimate the depth to garbage layers, water table, buried construction debris, and peat layers.
- GPR provides continuous spatial coverage, flexible observation depth, moderate to high resolution of subsurface features, and greater confidence in resource assessment.
- Compared with conventional mapping techniques, GPR can provide in a relatively short time the large number of observations needed for site characterization and resource assessments.
- GPR is noninvasive. In urban areas, the use of GPR can reduce hazards associated with soil borings and excavations.
- Interpretations were used to update soil survey reports.

Acknowledgements

The authors wish to express their appreciation to Humberto Hernandez (USDA-NRCS East Region Conservationist) for his support to our participation in this conference and to Tammy Nepple (USDA-NRCS National Soil Survey Center) for organizing, editing, and printing this poster.

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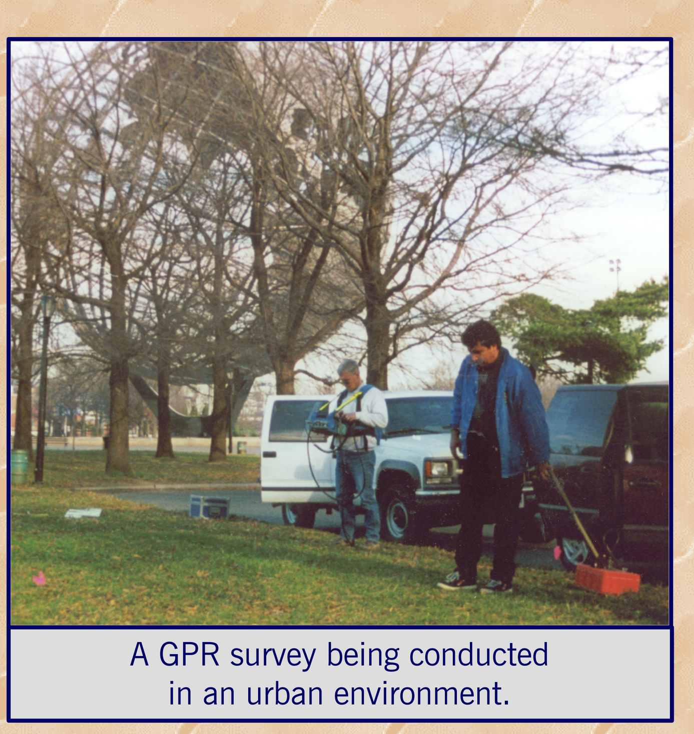
A GPR survey being conducted in an urban environment.

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